



## Essay

## Sleep, sleep timing and chronotype in animal behaviour



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In humans, sleep duration and sleep timing have been identified as interesting facets of individual differences and of personality. Sleep duration and sleep timing are different constructs. For example, compare two individuals both sleeping for 6 h: one may sleep from 2300 to 0500 hours and the other from 0100 to 0700 hours. One can assess the midpoint of sleep in these two subjects which is the midpoint in clock time between sleep onset and awakening. These ideas have already been picked up in a handful of studies. Sex differences have been found in birds in the same direction as in humans with males sleeping for less time. Contrasting effects have been found in relation to mating: in humans, late chronotype men have the highest mating success, whereas in birds, earlier chronotypes gain higher mating success. Many sleep parameters are related to assortative mating in humans and similar but weaker relationships have been found in birds. Ontogenetic studies show that sleep–wake behaviour changes during adolescence in humans. Such changes have also been found in other mammals ranging from primates to rodents. Factors determining sleep–wake patterns could be environmental, such as temperature, sunrise or sunset or even artificial light at night. Artificial lighting at night leads to an earlier wake up and singing time in blackbirds, *Turdus merula*, whereas light at night makes humans wake up later. As a conclusion, I show some parallels and differences in the study of sleep timing between animals and humans and encourage further studies, in both field and laboratory settings.

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In humans, sleep duration and sleep timing have been identified as interesting facets of individual differences (for a review see [Adan et al., 2012](#)), and in personality psychology, these aspects have received an increasing amount of interest demonstrated by several studies published during the last decade. The results of these studies might also have implications for the study of animal behaviour because these fields of studies (animal behaviour and psychology) have had an influence on each other. Sleep can be classified (apart from physiological measures, such as EEG) in the field by the variables sleep duration (in hours, minutes), sleep fragmentation (or in humans ‘sleep quality’) and sleep timing or chronotype. In humans, sleep timing is an extremely variable trait, with some people going to bed at a time when others get up. The extremes have been labelled colloquially as morning ‘larks’ and evening ‘owls’, although the distribution is more or less normal (e.g. [Roenneberg et al., 2004](#)). This variability makes sleep timing interesting for the study of individual differences. Ironically, one may argue that this huge variance is the most obvious trait separating humans from other animals.

However, this chronotype or preference for given bed and wake up times is stable over time and heritable and fulfils the criterion of a personality measure. The questionnaires designed to measure this chronotype have high test–retest reliabilities (and stability over time) with >0.80 in several studies ([Di Milia, Adan, Natale, & Randler, 2013](#)). Probably, this large variance in humans has evolved since the use of artificial lighting, starting with fire at night some hundred thousand years ago: while some of the group were sleeping, others probably stayed up on watch. This night-time vigilance could have been important for predator avoidance.

Sleep timing is independent of sleep duration ([Roenneberg et al., 2004](#)): With two people both sleeping for 6 h, one may sleep from 2300 to 0500 hours and the other from 0100 to 0700 hours. Based on simple clock times, one can assess bed times, sleep onset times, wake up and get up times; for humans such data are usually sampled in sleep laboratories, but large questionnaire surveys show that self-report data are in good agreement with real behaviour ([Thun et al., 2012](#)). In their study, [Thun et al. \(2012\)](#) reported correlation coefficients of around 0.5 between self-report sleep–wake behaviour and actigraphically assessed real sleep–wake behaviour. This adds validity to the measurements based on questionnaires. [Roenneberg et al. \(2004\)](#) used the midpoint of sleep as a single circadian phase measure to

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classify human chronotypes. This value is the midpoint in clock time between sleep onset and awakening. In the example given above it would be 0200 for the first and 0400 for the second person.

### *Chronotype as a Personality Aspect*

Sleep timing or chronotype has been described as an interesting aspect of personality (Matthews, 1988). The term 'personality' was first used for humans, but animal personality is also an increasing field of study, with articles by Gosling and John (1999) and Gosling, Kwan, and John (2003) being an important starting point. The first reviews (e.g. Réale, Reader, Sol, McDougall, & Dingemanse, 2007) labelled these personality aspects as temperament, a definition paralleled, for example, by personality psychologists such as Cloninger (1994) from the biological psychology field. Cloninger (1994, p. 266) defined two components of personality: temperament and character. 'Temperament can be defined in terms of individual differences in percept-based habits and skills (i.e. related to procedural memory and learning), which are regulated by the amygdala, hypothalamus, striatum, and other parts of the limbic system. In contrast, character can be defined in terms of individual differences in concept-based goals and values (i.e. related to propositional memory and learning), which are encoded by the hippocampal formation and cerebral neocortex'. Réale et al. (2007) also focused in their review on temperament and defined the following major trait categories: shyness–boldness, exploration–avoidance, activity, sociability and aggressiveness. Some of these dimensions are reflected in typical human psychological concepts of personality; for example, aggression–hostility and activity are found in the Zuckerman–Kuhlman personality questionnaire (Zuckerman, 2002), and sociability is part of the extraversion construct in the Eysenck personality inventory (Eysenck, 1970) and elsewhere. In other animals, Dingemanse, Both, Drent, van Oers, and van Noordwijk (2002) reported repeatability indices between 0.27 and 0.48. This is an important aspect since personality is defined as a trait construct that shows similar behavioural responses across time and situations. Similarly to these studies on the different personality dimensions in animals, the study of sleep and sleep timing may receive further interest from animal biologists, with some interesting studies having already been published (see below). In this essay, I show how studies on humans may have an influence on studies of nonhuman animals, and I try to propose further topics for research.

### **CHRONOTYPE IN ANIMALS**

In laboratory animals, there is some evidence for the existence of chronotypes (Aschoff & Wever, 1962a; Labyak, Lee, & Goel, 1997; Wicht et al., 2014). For example, Aschoff and Wever (1962a) reported individual differences in chaffinches, *Fringilla coelebs*. Labyak et al. (1997) examined 15 variables of circadian activity and temperature for diurnal degus, *Octodon degus*: they noted similar chronotype variations as described for humans with extreme individuals differing by one or more standard deviations from the population. For example, evening degus displayed a significant delay in the phase of minimum core body temperature. Similarly, different strains of mice, *Mus musculus*, had different chronotypes as measured by their median time of activity (Wicht et al., 2014). This idea of the chronotype was followed by Steinmeyer, Schielzeth, Mueller, and Kempenaers (2010) who investigated, with video cameras, different sleep variables in free-living blue tits, *Cyanistes caeruleus*, such as time of entering and leaving the nestbox, sleep

onset, awakening time, sleep duration, midpoint of sleep, latency to sleep and frequency and duration of nocturnal awakenings. These authors showed that there is variance in these variables, which is important for assessing correlates and evolutionary consequences ('individual differences'). Repeatability estimates showed that individuals were consistent in their sleep behaviour which is another important aspect if sleep behaviour is labelled a trait or a personality facet. These findings show that both blue tits and humans have a consistent sleep–wake pattern. Steinmeyer et al. (2010) assessed a variety of sleep–wake variables and an important aspect of further studies in animal behaviour is to assess whether the midpoint of sleep (or median activity) or any other variable of the sleep–wake cycle is most important for classifying animal sleep–wake behaviour; some studies might lead to the conclusion that the most important variable is wake-up time. However, this has yet to be assessed in different species. Another question is the heritability of this trait. In humans, it has been shown that chronotype is heritable, with a high overall heritability of about 50% (Adan et al., 2012). The candidate gene approach has identified a catalogue of polymorphisms in clock genes that show associations with different chronophenotypes (Adan et al., 2012; Hasan et al., 2014). Helm and Visser (2010) showed for great tits, *Parus major*, that there is also ample genetic variation and high heritability in sleep behaviour in wild birds. In conclusion, individual differences in sleep–wake behaviour can be seen as an aspect of temperament because the trait is partly heritable, stable and subjected to sexual selection.

### **PHYSIOLOGICAL ASPECTS**

In nonhuman animals, chronotype has not yet been studied extensively in relation to hormone measures or other physiological measures in field studies. However, there is some evidence for such relationships from humans, both men and women from laboratory and field settings. First, body temperature was lower at night and the lowest core body temperature (the point of lowest temperature) was earlier in the night in morning than in evening types, both in the laboratory (Baehr, Revelle, & Eastman, 2000) and in field settings (Sarabia, Rol, Mendiola, & Madrid, 2008). Melatonin secretion was correlated with chronotype, that is, earlier chronotypes had an earlier peak in melatonin secretion than later chronotypes (Burgess & Fogg, 2008). Cortisol levels were higher in the morning in morning types, which was interpreted as the higher cortisol levels preparing morning types for the day and may explain why morning types get out of bed more readily and reach their peak performance earlier than evening types (Randler & Schaal, 2010). Testosterone, on the other hand, was higher in evening-type men when measured in the morning between 0800 and 0900 hours (Randler et al., 2012b). This might in turn be related to their mating success (see below). Measuring hormone levels of different chronotypes might, therefore, be an interesting topic for animal behaviour research.

### **ONTOGENETIC ASPECTS AND SEX DIFFERENCES**

Ontogenetic aspects have been discussed in detail for humans, and it has been found that there are two significant changes in sleep–wake behaviour during adolescence (Roenneberg et al., 2004). First, with the onset of puberty, children very quickly become evening oriented around the age of 12–14 years (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Randler, 2011). This has been supposed to be related to pubertal changes in hormone secretion, although this idea has not been convincingly tested. Second, at the end of adolescence there is a return to morningness which has been viewed as a marker for the end of

adolescence (Roenneberg et al., 2004). However, these changes in sleep–wake behaviour are not unique to humans (Hagenauer & Lee, 2013). Hagenauer and Lee (2013) reported changes in behavioural and physiological sleep parameters during adolescence in nonhuman mammalian species, ranging from primates to rodents. Changes in sleep–wake behaviour have been found in rhesus monkeys, *Macaca mulatta*, with an activity delay, degus, *O. degus*, laboratory rats, *Rattus norvegicus*, laboratory mice and fat sand rats, *Psammomys obesus* (Hagenauer, Perryman, Lee, & Carskadon, 2009). However, the overt appearance of these changes is species-specific, with polyphasic sleepers, such as rodents, showing a phase advance in sleep timing (Hagenauer & Lee, 2013).

Sex differences of about 15 min have been found in blue tits (Steinmeyer et al., 2010) in a similar direction as in humans: in both species, females sleep for longer as reported in large epidemiological studies (Randler, 2011; Roenneberg et al., 2004; Roenneberg, Kuehnle, et al., 2007). In a laboratory setting women and men had the same sleep timing ( $N = 56$ ) but the timing of the circadian rhythms of core body temperature and pineal melatonin secretion was earlier relative to sleep time in women than in men (Cain et al., 2010). In another study, Duffy et al. (2011) reported that the intrinsic circadian period was significantly shorter in women (24 h 5 min  $\pm$  12 min) than in men (24 h 11 min  $\pm$  12 min). Davis, Darrow, and Menaker (1983) showed in hamsters, *Mesocricetus auratus*, that during entrainment to a 24 h light:dark cycle (LD 14:10), females began their daily activity earlier than males. As studies in the field are scarce, assessing sex differences in different animal species in field settings might be rewarding, and might be possible by webcams or similar methods (Steinmeyer et al., 2010).

## EXTERNAL ABIOTIC ENVIRONMENTAL INFLUENCE

Large seasonal differences in sleep timing of 4.8 h between summer and winter have been found in blue tits, and these differences are much larger than in humans. In humans at around 69° latitude in Norway (Tromsø), the difference was only some 8 min which was an unexpected result (see Johnsen, Wynn, Allebrandt, & Bratlid, 2013). A similar effect as in the blue tits was expected (but with a weaker difference of 30 min or 1 h). Environmental factors determining sleep–wake patterns could be temperature, sunrise or sunset or even light at night or noise. Lehmann, Spoelstra, Visser, and Helm (2012) showed experimentally that ambient temperature had an influence on the circadian clock. Lehmann et al. (2012) found that under constant dim light conditions individuals lengthened their free-running period (i.e. the time taken for a full sleep–wake cycle under constant conditions) at higher temperatures by  $5.7 \pm 2.1$  min. Great tits kept at 18 °C started activity later and terminated it much earlier in the day than those kept at under 8 °C; overall, at the higher temperature the chronotype was slightly earlier and the duration of activity was shorter. Similarly, it has been suggested that humans are earlier chronotypes in warmer climates and epidemiological evidence indeed showed that chronotypes are earliest in the tropics (Borchers & Randler, 2012; Randler, 2008). However, at least in humans, it is yet unclear whether it is the effect of temperature per se or the influence of sunlight regime (used by proxies such as latitude and longitude). For example, in the tropics, the day length is also more constant than at higher latitudes, which could influence biological rhythms. It should be much easier to disentangle the effects of the light regime from that of temperature in animal models than in humans because they can be independently changed. Similarly, there is a longitudinal gradient: within the same time zone: people in the east get up and go to bed earlier than people in the west (see, e.g., Randler, 2008; Roenneberg, Kumar, & Merrow,

2007). This longitudinal gradient should also be present in different animal species and could be compared in the field in hole-nesting birds for which local factors (darkness of the nest cavity) as well as longitudinal factors (earlier sunrise in the east) should contribute to the variance in sleep–wake behaviour (see discussion in Aschoff & Wever, 1962b). However, research on light conditions and their consequences for birds is just emerging (Wesołowski & Maziarsz, 2012) and it is expected that these factors should interact with each other (and with more general factors such as sunrise and the darkness of a nest cavity).

Artificial light at night has been identified as an emerging problem for animals and humans. For example, it affects dawn activity in birds: in four out of five songbird species, the dawn song in males near street lights started significantly earlier than in males in a forest (Kempnaers, Borgström, Loës, Schlicht, & Valcu, 2010). Birds exposed to light at night developed their reproductive system up to 1 month earlier, and also moulted earlier, than birds kept under dark nights (Dominoni, Quetting, & Partecke, 2013). This is another finding that parallels studies on humans but again in an opposite direction: light at night makes humans later chronotypes; thus they go to bed later but also get up later (Vollmer, Michel, & Randler, 2012). Therefore, one could also expect that birds 'go to bed' later in a highly artificially lit environment but probably might also 'get up' earlier (as shown by Dominoni, Helm, Lehmann, Dowse, & Partecke, 2013). Although the earlier 'get up' and dawn song has been demonstrated in some studies, the later bed times have been controlled only in one study (Dominoni, Carmona-Wagner, Hofmann, Kranstauber, & Partecke, 2014). This topic could be interesting for further studies. Dominoni et al. (2014) reported an advanced onset of daily activity in urban sites compared with rural ones, but the end of the daily activity did not vary between sites. This is an interesting result and requires further research. Comparably to the dawn song in songbirds, the evening singing in nocturnal birds (e.g. owls) should start later in an environment with more artificial light. Within the same species, an earlier get up time in conjunction with a later bed time would lead to general sleep deprivation in urban animal individuals (compared with rural ones), which may have consequences similar to those seen in humans (see below). If sleep reduction happens only during a given (short) time period, animals may compensate for it. Further, it may have different effects on migrant and resident birds because migrants may experience less light at night in their winter quarters than the residents. Such aspects could be controlled and manipulated in nestbox study sites based on an intraindividual comparison. In the laboratory, for example, light regime could be shifted simply by later lights-on – lights-off regimes to assess how individual birds respond to changes in the light conditions (or, in this case, to a manipulated sunrise–sunset regime). Further, the influence of light at night and its impact on sleep or on physiological measures could be experimentally tested in the laboratory by providing artificial light at night. The effect of light on sleep is interesting because many physiological processes are affected by light and research on this topic could be done in cross-over experiments and individual differences could be assessed. For example, light at night might affect sleep fragmentation and should induce a stronger stress response. Studies on animals may also have implications for human behaviour. For example, birds exposed to light at night developed their reproductive system up to 1 month earlier (Dominoni, Quetting, et al., 2013), and thus it would be interesting to assess differences in these reproductive aspects in humans living in highly artificially lit cities compared with areas with less 'light pollution'. Perhaps light pollution affects sexual maturation. Some studies in humans provide evidence that light at night may be involved in the emergence of cancer (Kloog, Stevens, Haim, & Portnov, 2010).



Another interesting aspect in humans is the large difference between weekdays and weekend or free days, owing to school or work schedules. People usually delay their sleep–wake pattern at the weekend and get up and go to bed later. According to the differences in schedules, one might also expect an influence on animals because disturbing noises (such as traffic) should be lower and later during weekends while outdoor leisure activities should then peak. These leisure activities could have implications for disturbance ecology. Further, it is expected that the consequences of disturbances might start later on the weekends and this might be a possible time frame that could be used by flexible species. Studies about time and space use in urban animals and in natural settings could compare these aspects and find out whether and how species use these open time frames flexibly, and if there are species-specific differences, for example whether some species adapt to a flexible schedule more easily than others. However, two recent studies assessed the effect of variation in anthropogenic noise between weekdays/weekends and specific times of year (daylight saving time change) on urban birds' activity timing and they found contrary results. Nordt and Klenke (2013) reported that noise seems a more important driving factor than artificial lighting affecting the start of the dawn song in urban blackbirds, *Turdus merula*, but it was not clearly separable from artificial lighting. After daylight saving time started, human activity (including noise production) was 1 h earlier in relation to sunrise, and this should have affected the singing blackbirds, but the authors showed only weak effects. So if noise is the driving factor, the effect of daylight saving time should be more pronounced. However, these changes were assessed only during 1 study year, and other yet undiscovered environmental conditions could have masking effects. Such studies should be replicated in different species at different places and during different years. In contrast, Dominoni et al. (2014) reported that noise levels were significantly different between weekdays and weekend days while artificial light at night was similar, and they concluded that it is the light regime rather than the ambient noise that is a driving force in influencing sleep–wake rhythms.

## SEXUAL SELECTION AND MATING

The sex differences in sleep–wake variables in the blue tit were considered as an effect of sexual selection, similarly to humans (Randler et al., 2012a). Blue tit males that 'went out of bed' earlier had a higher mating success (Poesel, Kunc, Foerster, Johnsen, & Kempenaers, 2006). This is supported by Helm and Visser (2010) who reported that the shorter free-running period length (shorter than 24 h in dim light) may be a consequence of sexual selection. Offspring from extrapair matings had significantly shorter free-running periods than their half-siblings from within-pair matings, which, in turn, leads to earlier awakening time, which, again, may foster extrapair matings (Helm & Visser, 2010). However, the opposite effect has been found in humans: evening men had a higher mating success even when controlling for factors such as going-out frequency and extraversion, a personality trait correlated with higher mating success (Randler et al. 2012a). This is not a real contrast because in humans, the marketplace is in the evening, so men with a higher endurance and evening orientation should perform better in the mating game (Randler et al., 2012a). Piffer (2010, pp. 361–362) argued that 'the most likely way in which sexual selection could have acted on human sleep patterns is through a lek-display system, taking place at night, when people were free from foraging activities or other tasks and stayed closer to each other in order to defend themselves from predators'. Piffer (2010) described how in ancient societies and in societies that are close to our probable ancestors (e.g. the Wadabe of Niger; Piffer, 2010), men often gather in the evening, prepare clothing and

make-up, line up and perform dance activities (somewhat similar to modern discotheques). Further, it is assumed that in more ancient societies, some 'lek-like' display happened in the evening and at night. Another line of evidence is that sexual activities in humans take place during the night, usually between 2300 and 0100 hours (Refinetti, 2005). This finding was corroborated by a higher saliva testosterone level in evening men (Randler et al., 2012b). In birds, however, ovulation is in the morning, so birds should benefit from rising early and should sire more extrapair offspring (Poesel et al., 2006). In a study on sleep duration/sleep loss, Lesku et al. (2012) reported that male pectoral sandpipers, *Calidris melanotos*, were able to maintain high neurobehavioural performance despite extensive sleep loss during courtship and the most 'sleepy' males sired the most offspring. Sleep duration is not related to mating success in humans (Randler et al., 2012b). In addition, in humans, eveningness is associated with other personality traits that are beneficial for short-term mating success, such as extraversion, impulsivity and risk taking (Maestripieri, 2014); thus such relationships could be investigated in animals in conjunction with sleep behaviour, for example boldness–shyness or exploration–avoidance could be somewhat related to risk taking. Although there seems an effect of sexual selection, assortative mating may occur. Concerning sleep–wake variables, in humans assortative mating is related to many sleep parameters (chronotype, bed time, rise time; Randler & Kretz, 2011). These correlations between the sleep–wake variables (rise time and bedtime) existed on weekdays and on the weekends, the association being higher for weekends when sleep is less influenced by social and work schedules. Steinmeyer, Müller, and Kempenaers (2013) found that in blue tits social breeding partners were mated assortatively only with regard to awakening time, but not in other sleep parameters. This result is interesting since it shows that assortative mating might be not as important with these traits; however, further studies in different species are needed to shed light on this relationship. The assortment could also be a result of different mating strategies, for example there might be differences between humans where many partners look for long-term relationships, compared with other animal species that seek short-term relationships and extrapair matings. As there is much variance between species (and within species) in mating strategies this would make an interesting study.

## CORRELATES AND EVOLUTIONARY CONSEQUENCES

Health-related aspects have been revealed in relation to chronotype and sleep duration in different studies in humans (e.g. Lázár et al., 2012), late risers having worse health. For example, being overweight or obese has been linked with evening orientation and increased stress hormones (Lucassen et al., 2013) or generally an unhealthy diet (Kanerva et al., 2012). Also, health problems have been found with eveningness: there was a predisposition in evening types to type 2 diabetes, while compromised sleep was associated with arterial hypertension (Merikanto et al., 2013). Thus, late chronotypes might be at a disadvantage compared with earlier chronotypes. Correlates of sleep behaviour with other aspects of behaviour, such as offspring ratio, fitness and body condition, could also be tested. However, it might be also possible that these aspects of short sleep duration do not affect animals much at least in the short term. For example, sleep loss as an impairment has received much attention in the ergonomics literature and in neurobehavioural research with its relationship, for example, with cognition or decision making (Killgore, Balkin, & Wesensten, 2006; Lim & Dinges, 2010) but Lesku et al. (2012) found a high neurobehavioural performance (e.g. courtship display) despite extensive sleep loss during courtship in pectoral sandpipers and their results

challenged the view that decreased performance is an inescapable outcome of sleep loss. Thus, their study is in strong contrast to work on humans for whom sleep loss leads to impairment and decreased neurobehavioural functioning (e.g. correct decision making, [Killgore, 2007](#)). The disruption or shortening of sleep in this wader species may be in some way reflective of shift work in humans for whom changes in sleep–wake behaviour have an influence on health. Another interesting aspect concerning sleep duration has been recently found: increased aggression is related to short sleep durations ([Randler & Vollmer, 2013](#)). However, this study was conducted on a trait level and should be replicated on a state, or situational, level. The assessment of aggression could be done in laboratory settings where sleep restriction or disturbance is easier to achieve than in a field setting and could be related to outcomes of aggressive encounters or to risk-taking behaviour.

## CONCLUSIONS AND FURTHER TOPICS

What can psychologists learn from animal studies on sleep behaviour? Animals are less restricted or influenced by social schedules (e.g. work or school in humans) and the comparison of results from animals and humans may help researchers assess social aspects of sleep behaviour and their importance for the circadian rhythm. More social animals, such as baboons or meerkats, might have higher synchronization in their sleep–wake behaviour than solitary species. What can be learnt from studies on human sleep behaviour? It seems worth scrutinizing the psychological literature on humans to gain ideas for the study of sleep and sleep timing in animals. On a more general basis, factors determining chronotype could be assessed (genetic, environmental, social, etc.) and correlates of chronotypes might be a good topic for further research. The study population could be sampled under semi-naturalistic conditions, for example in nestboxes where light from outside could be measured or illumination could be placed to disrupt the circadian clock or to simulate sunrise. The effect of genetics and evolution should be less than in humans because there should be a stabilizing selection on wake up and bed times in animals. However, behavioural flexibility in sleep timing should differ between guilds and species, for example among tropical birds (experiencing a stable day–night rhythm), birds of the high arctic (experiencing large fluctuations; more resembling shift workers) and migrating songbirds (retaining a more or less stable day–night rhythm, but varying latitude and temperature). From a more psychological viewpoint, the ‘morning affect’ has been assessed by questionnaires, in addition to simply measuring waking and retiring times. This ‘morning affect’ could be assessed, for example, by questions such as ‘How alert do you feel after getting up?’ ([Di Milia & Randler, 2013](#)). Although this cannot easily be assessed in other animals, there might be individual differences in reaction times, vigilance or foraging efficiency in animals depending on time of day or in the first minutes after awakening, thus also representing some kind of ‘morning affect’. This might be interesting, since in the early morning, the trade-off between feeding and antipredator behaviour should be optimized, and birds that best address this need should have an advantage; for example, individuals that have a higher ‘morning affect’ should perform better in this trade-off. Further, personality in humans has been correlated with sleep timing in different ways and by different personality inventories ([Adan et al., 2012](#)), for example with late chronotypes scoring higher on impulsivity and sensation seeking. As sensation seeking is at least partially related to variation in the dopamine D4 receptor gene (*DRD4*; [James et al., 2007](#)) one would expect possible association of the D4 receptor gene with aspects of sleep timing. As a final conclusion, psychological studies on humans should be used to develop research ideas for chronotype and sleep in animals.

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